UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

Save the Turtles

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UNIVERSITEIT TWENTE.

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Chapter 0: Introduction

We are Team 20, Save The Turtles, consisting of 7 students: Luuk Wessels (team leader), Marleen de Ruijter, Rint Rutgers, Mette Laros, Daan Strijbosch, Thiago Albrecht and Twan de Groot. The goal of this project is to create a smart environment that can help with humanity's ongoing struggle regarding climate change.

Climate change brings many problems with it and the effects can be seen in every aspect of our society. One of the big problems that climate change brings with it is that humanity has to change their relationship with water. The general rule is that whenever the temperature rises 1 degree Celsius air can hold 7% more water. [0.1] Due to this, long periods of heavy rainfall will become more common. These periods of heavy rainfall have already shown to be devastating to multiple regions, even regions which previously never experienced this phenomenon. It is estimated that by 2030 25 extra countries will experience increasing floods, in addition to the already 32 countries that are impacted at present. [0.2]

To contribute to a solution for this problem, we came up with multiple solutions ranging from plastic dikes to flood detection. In the end we came up with a solution that would help with resilience whenever a flood occurs. Whenever a region faces heavy rainfall, sewers are likely to get clogged resulting in water having no place to leave the area. By being able to detect where these clogs happen as soon as possible, they can be resolved more quickly and thus reduce the strain put on areas targeted by heavy rainfall. [0.3]

To realize this we decided to place multiple ultrasound sensors along sewage pipes. These pipes will monitor the water level carefully and with strategic placement we can pinpoint locations of clogs precisely. In this report we will go further in-depth into our research on the topic, the solutions proposed, why we chose our final solution and the methodology, validation and results of our solution.

Chapter 1: Literature Review

Article 1 - Can reforestation uproot climate change? [1.1]
Reforestation is a way to capture CO2, therefore it can uproot climate change. But it is very important to make sure you are doing it the right way. When you plant a tree you have to pay close attention to what type of tree you plant, and where you plant this tree. That means that you have to plant native trees in natural areas, otherwise the projects could even increase C02-emissions by damaging the environment. Other disadvantages of reforestation is that it takes a lot of time and dedication. But when you succeed there are a lot of positive side effects. It increases biodiversity and it improves the habitat of the animals living in that environment.

Article 2 - How can education contribute to awareness and action on climate change? [1.2]
"Education is critical in helping populations understand and address the impacts of climate change, and in encouraging the changes in attitudes and behaviour needed to help them address the causes of climate change, adopt more sustainable lifestyles and develop skills that support different modules of economies, as well as to adapt to the impact of climate change." This is called climate literacy. Education about climate change promotes future citizenship that is environmentally and socially responsible on a global scale.

Article 3 - Earth suffers as consumerism spreads [1.3]
Most of the environmental issues we see today can be linked to consumerism, it has a devastating toll on earth's water supplies, natural resources and ecosystems. Consumerism is partially caused by the need for simplicity, luxury and the throw-away mentality. Examples of these are highly processed foods, which takes a lot of water to make. Cars, which causes pollution and more need for fossil fuels.

Article 4 - The world's food supply is made insecure by climate change [1.4]
In the next 30 years, food supply and food security will be severely threatened if no action is taken. Future projections of both maize and wheat indicate a significant decline. Especially in many African and Central American countries, maize is an important component of diets. Wheat is important too since it provides about 20 percent of the world's calories and protein. Next to this it is also projected that the fishing industry will experience significant disruptions meaning that fishing yields will also decrease. To combat the increasing strain from climate change the global food system will need to become more resilient.

Article 5 - Water security and climate change [1.5]
Climate change is likely to create big problems regarding water security. Studies have shown that climate change increases the vulnerability of fresh water sources. The effects of climate change, like rising temperatures and more extreme weather events are likely to affect water resources by: boosting evaporation, snow falling as rain, melting of glaciers, increase of floods and droughts and wildfires. A clear solution to this problem is yet to be found, however since many other climate change mitigation strategies rely on water as an input it is becoming more and more clear that we need to improve water security.

Article 6 - The Global Impacts of Rapidly Disappearing Arctic Sea Ice [1.6]
Arctic sea ice melting is probably one of the most well-known effects of climate change. The phenomenon occurs due to the fact that CO2 emissions rise and the ocean warms up. Arctic ice melting brings many problems with it, most importantly the sea level rising and engulfing many pieces of land. Next to this wildlife is also threatened by arctic sea ice melting. Another worrisome problem is that melting permafrost is suspected to be the cause of new outbreaks of diseases, an example of this phenomenon is Anthrax.

Article 7 - Climate change, extreme weather events and respiratory health [1.7]
Climate change alters air pollution patterns in severely urbanised areas. Studies show consistently that air pollution is combined with heatwaves, which causes extreme weather conditions. These changes in weather can severely impact respiratory health. The impact on human health can vary from changing allergy patterns to chronic respiratory diseases and in some cases premature death. Respiratory diseases, especially allergic diseases for example asthma and rhinitis, are increasing worldwide, but especially in urbanised areas, where air pollution is generally higher. The increase is so big that it can't be related to genetic problems. Outside factors such as the primary and secondary effects of climate change play a big role in the increase of these diseases.

Article 8 - Impact on agriculture production and sustainable solutions [1.8]
Rising temperatures and extreme weather conditions result in for example droughts and floods. This extreme weather has a lot of impact on agriculture, harvests fail. The result of failed harvests is food shortages and economic problems. Food shortages increasingly become more of a problem with the growing world population. These food shortages will even become a larger problem because of the growing population, since more space is needed to grow crops and keep livestock, which will result in more deforestation. Climate change already results in a lot of land degradation and desertification. Deforestation to make place for agriculture only increases the speed of these processes. A quarter of the earth is already degraded, which has an impact on the lives of approximately 1.5 billion people. The degraded and deserted land is not only a problem for agriculture, but soil is one of the biggest sinks of carbon dioxide.

Article 9 - Ecosystem-based management of coral reefs under climate change [1.9]
Coral reefs have the highest regions of biodiversity in oceans. Humans rely on coral reefs for a lot of food production. Increasing carbon dioxide levels in the ocean cause the coral reefs to bleach, the reefs are no longer able to gain energy from photosynthesis and will eventually starve to death. Many organisms can't live in dead corals, and will therefore go extinct. This is also problematic for communities that rely on fishing for a living. High carbon dioxide levels will make the reefs more prone to coral diseases, and delay the recovery. Scientists predict that in 2050 the reefs will erode faster than they will grow, which results in reef dissolution.

Article 10 - Plastic and trash in the oceans [1.10]
Plastic in our oceans has a disastrous effect on the animals and other organisms that inhabit it. The oceans absorb a lot of carbon dioxide, which helps to cut down on climate change. The ecosystem in the water can not stay healthy and balanced if plastic and trash are present. Removing these would help a great deal to keep these environments operating as they should.

Article 11 - Climate change and diseases [1.11]
Many infectious diseases and their rate of spreading are affected by temperature changes, humidity and other factors which are known to be increased by climate change. Vector-borne diseases for instance are spread by living organisms, such as mosquitos or ticks. Mosquitos especially are known to do well in warm and humid climates. Other than that, climate change will also have an effect on human behaviour, as more land becomes uninhabitable, trade could well increase as land use changes and water availability could cause problems. Both these factors could very well impact how vector-borne and infectious diseases spread and how many new variants become problematic in a negative way for humans.

Article 12 - Climate change and education for adaptation [1.12]
One of the most important factors in climate change is human behaviour. We as a species have a direct impact on the climate of our planet. Education is a great tool to create more awareness and ensure that everyone does what they can do to lower their impact on the environment. We often think of big factories and airplanes when we are talking about climate change, but this is not the only contributing factor to climate change. If 7.75 billion people all decreased their water use, plastic use and travelling for instance that would change everything. This is of course not realistic, but that doesn't mean we should give up. Educating as many people as possible in a way that actually changes their behaviour would still have a big impact.

Article 13 - Climate change and pandemics [1.13]
Pandemic risk can be increased by some of the same causes of climate change. Deforestation, usually done for agricultural purposes, is the leading source of habitat loss around the world. Because of the loss of habitat, animals are forced to move, where they may come into touch with other animals or people and spread viruses and other contagious agents.
Large livestock farms can potentially be a source of infection transmission from animals to humans. Reduced demand for animal meat and more environmentally friendly animal husbandry could reduce the danger of developing infectious diseases and reduce greenhouse gas emissions.

Article 14 - Climate change and respiratory health [1.14]
The use of fossil fuels can also have a direct impact on human health.
Burning fossil fuels pollute the air, which adds microscopic particles that can get into the lungs and heart, and even go into the circulation, potentially triggering strokes and heart attacks. These particles may cause direct damage to organs or trigger an inflammatory reaction from the immune system as it attempts to combat them.
Moreover, pollution also affects people with allergies.
For example, CO2 raises the acidity of the air, which causes plants to release more pollen. Although this may only increase the frequency and duration of some people's allergies, this can be life threatening for others with more severe allergies.

Article 15 - Climate change and world hunger [1.15]
Poorer countries, which contribute the least to the problem of climate change, will feel the consequences of climate change at a higher level than richer countries regarding hunger and food crisis. Those countries already suffer from poverty, malnutrition and enormous inequalities, and a lot of the population - if not a big part of the country's economy itself - rely on agriculture. This means a more difficult access to nutritious foods by low-income communities, and increased food insecurity.
Fisheries are also affected, as higher ocean temperatures and pollution affects marine life in general, further increasing the risk of food insecurity for communities that rely on fishing as a main source of nutrition or income.

Article 16 - effects of heating ocean on fish[1.16]
Due to climate change the ocean is also heating. The ocean is holding more and more heat. Not only is this dangerous for the coral reefs, but this also has an effect on marine life. The size of the fish species is changing rapidly. It seems that small fish are getting smaller and big fish bigger. After a certain time, this can result in an imbalance in the ecosystem. The size is not the only thing that changes under water, also the location that the fish are swimming in is changing. Also this shift in location affects the ecosystems.

Article 17 - Droughts and climate change [1.17]
One of the most important things to humans in water. We not only use it to drink but also use it in architecture, construction and much more. Our society relies a lot on water, but there is more and more scientific proof that climate change also has an influence on droughts. Some studies show that droughts that used to occur once in every decennium, occur now 1.7 times more often. A NASA study shows that by the year 2050 the chance of a megadrought will be 60 percent, compared to the 12 percent that it is now. This shows that drought is a big problem that we should take seriously. There are already a lot of actions trying to reverse local weather changes, but we should also work on emergency backups for when the droughts get serious.

Article 18 - Soil and climate change [1.18]
Human and ecological systems rely on soil for the provision of water and nutrients for plant growth, the regulation of the water cycle and the storage of carbon. All the climate changes will not only affect us but also the way that soil provides these services. It may also be good to know that soil is the second largest carbon poule after the oceans. Because of the accessibility and the relatively low cost of storing carbon in soil it could even be a big part of a short term solution to climate change. It is also important to keep the carbon in the soil, as if only a small portion of the soil carbon stock would be released, it could mitigate the winnings somewhere else.

Article 19 - Chemicals and climate change [1.19]
Manufactured chemicals are an important part of the provision of a large range of goods and services that greatly support our lifestyle and economics. However a lot of these chemicals are proven to be dangerous for humans in very small amounts. The growing understanding of these substances and the growing production might be a problem for the environment because for a lot of these substances we don’t yet know how they pass through the environment and affect living organisms at varying concentrations.

Article 20 - Influence of climate change on biodiversity [1.20]
Not only because our deforestation and hunting do some species die out. Also because of climate change a lot of species encounter hard times to survive. One of the biggest problems is that biodiversity decreases a lot. This can cause a destabilization in ecosystems which can cause a lot of trouble. The decrease in biodiversity can cause a big shortage in available food for some animals which can cause starvation. Our planet still has thousands and thousands of species, if we do not watch our species well enough, we will lose a lot.

Chapter 2: Identification of General Problems and Challenges

Topics and problems:

- Respiratory problems due to **air pollution**
  - Why is it important: air pollution is an important factor in the global increase in respiratory problems. These respiratory problems cause a lot of diseases and even death.
- Food shortages and **agricultural problems** (vertical agriculture)
  - Why is it needed: many studies have shown that due to climate change many food sources will become less useful or even completely useless. Together with the population steadily increasing this will put large strains on food supplies. Agriculture will need to adapt for food to stay available.
- **Education** to change people's behavior and teaching about sustainable choices.
  - Target groups: people who want to help reduce climate change, but do not know how to make smart decisions.
    - Examples: separating trash, reducing plastic use, picking right brands to buy from, meat reduction
  - Why is it needed: small changes can help a lot, especially when a lot of people implement these small changes.
- Climate change vs. **diseases**/Pandemics
  - Why is it important: An increase in diseases that spread around the world (pandemics) disrupts our daily lives in an extreme way. More people will die than normal and we will not be able to do many of the social activities that we used to enjoy if infectious diseases rule our lives.
- Removing **plastics** from our ecosystem
  - Why it is needed: Plastic in our oceans specifically causes a lot of damage to the environment. It destroys nature and ultimately ends up on our own plates when we eat fish.
- **Consumerism** and making people aware of the vicious cycle.
  - Why is it needed: Consumerism is part of a larger circle. From extraction, production, distribution, consumption and disposal. In this circle there is a lot of water wastage and CO2-emissions. To stop this whole circle you need to tackle the problem at the origin: consumerism.
- Decrease in **biodiversity**
  - Why is it important: Biodiversity is important because it is needed to have a balance in ecosystems. When the ecosystems are not in balance it can cause catastrophic damage. Because of climate change the biodiversity and thus the ecosystems get in danger.
- Increase in **weather related disasters**
  - Why is it important: weather related disasters like wildfires and dust storms are increasing. Both wildfires and dust storms are a big source of air polluting particles that cause respiratory diseases to humans and animals.

Chapter 3: Identification of Relevant Problems

1. **Unsustainable agriculture**
   Many aspects of our food production are not sustainable and food production is one of the biggest contributors to climate change. Not only is food production responsible for 34% of man-made greenhouse gas emissions [3.1], many food sources are also put under pressure by climate change. The soil degradation rate for example is estimated to be 10-20 times (no tillage) to 100 times (conventional tillage) higher than soil formation rate. [3.2] Since agriculture is the number one most important source of food the urge to create more sustainable methods is extremely high.

2. **Inefficient education on climate change**
   To promote climate action and change of behaviour education is needed to make sure people are not climate illiterate. Climate literate people tend to take more action or are more careful with making green choices. When you want a large group of people to contribute to putting a halt to climate change, you need to educate people on the changes they can make themselves. Technology is a great way to reach more people

3. **Disease spreading increase due to climate change**
   Many diseases that pose a danger to society are spread by living organisms, also known as vectors. We can use technology to stop the rapid spreading of these vector-borne diseases, such as malaria which is spread by mosquitoes mainly. An example of technology used to stop the spreading of malaria is mSpray [3.3], which is an app that maps where insect repellant has been sprayed. Due to climate change the amount of insect pests have been increasing. This is mostly caused by the increasing heat; the insects need heat to stay alive and bread. The app creates a better picture of the protection in each area against mosquitoes and reduces overspraying in the same area.

4. **Microplastics in foods**
   Studies show that common foods such as fish, fruits and vegetables contain many particles of plastic (microplastic). The effects of microplastics in human health are still being studied to know the full extent of the impact of microplastics in our health, but there's already clear evidence it is harmful to human health.

5. **How to handle big amounts of water**
   Handling on the one hand the problems water will bring and on the other hand the constant need for water will be a big topic in the coming years. The general rule is when the air temperature increases by one degree, the air can hold 7 percent more water. And because of the change in the weather there will occur more and more often a heavy rainfall that can possibly flood cities or destroy houses. Heavy rainfall causes dikes to break, which floods crops and cities. Next to this the sea is projected to rise 0.3 meters above 2000 levels by the year 2100. And although it may sound like we will have an abundance of water, clean drinking water and water for agriculture is projected to be in short supply.

Chapter 4: Problem Selection and Motivation

How to handle big amounts of water

We chose the topic of excess water because there is no good solution for water management yet which will hold up to the expected amounts of water in the future. Scientists predict that the temperature will rise 2 degrees. With every degree 7% more water can be held in the air, resulting in more heavy rainfalls and floods. [0.1] Estimations already show that 179.2 million extra people will be exposed to floods by 2030. [0.2]

Next to this, the topic of the increasing impact of water is something that is close to us. We already saw it happening in the Netherlands when Limburg suffered from flooding and we are likely to see it happen more often in the future.

Furthermore, the topic of increasing amounts of water is a topic that is both broad and specific in a way. The problem itself is relatively small in scope but the different ways to tackle it are endless. Throughout the years we have already seen solutions aimed at attempting to solve this problem but evidently none have had the desired impact.

Finally, we also felt that the other problems we listed were either too difficult to solve with our knowledge, in the case of for example disease spreading, or too big in scope to satisfyingly solve during the time of our project.

Chapter 5: Potential Solutions

1. **Green roofs**
    - green roofs with plants to absorb extra water on roofs to prevent leaks.
    - green roofs also absorb carbon dioxide
2. **Plastic dikes**
    - use waste plastic to make dikes waterproof and cheaper
    - accessible for poorer countries
    - good use for waste plastic
3. **Usage of rain water over tap water**
    - collecting rainwater and making a system so you can water plants or flush the toilet with it
    - prevent unnecessary use of tap water.
4. **Water storage**
    - store water when there is too much of it (for example floods and heavy rainfall) so you can use it when there are droughts
    - Make a miniature model to show the impact of this storage
5. **Diverting the course of mud streams**
    - putting sensors on a mountain (humidity sensors in the soil). When water level rises, open up gates so the mud stream gets diverted. Maybe adding pumps to that as well.
6. **Collecting rainwater at the top of buildings**
    - to distribute the amount of water that comes in the sewage system you need to collect it in the buildings and bring it to the sewage system later
7. **Prevent/detect floods**
    - Finding different factors that can predict when a flood is going to happen and then diverting / storing the water
    - Flood monitoring system with notification alerts
8. **Sewage clog detection**
    - In a lot of areas that are affected by floods, the sewage system is bad or blocked by, for example, branches of trees and trash.
    - Sensors placed frequently inside sewages can detect the water level and with code detect blockages.
    - Sensors in the sides of sewer pipes that can detect rubber ducks, from those sensors we can calculate the speed and height of the water and see easily where the blockages are.

Chapter 6: Solution Selection

Sewage clog detection

We chose to work out the solution of sewage clog detection for a number of reasons. First of all it is the solution that is the most like a Smart environment, it is a specific place and not something big, like a whole mountain. Secondly, we think that this is something new. This is not a project you hear often and makes it a unique project. Next to that this is also something you can build a prototype for in the given type. Lastly, this solution can be implemented in a lot of places, this makes this project even more relevant because you can improve a lot of cities with this and therefore help even more people.

Tasks:

Task	**People**
Find the countries that are in need for this system (target audience)	Daan
Finding materials for the prototype	Luuk, Mette, Marleen, Rint
Creating the physical prototype	Luuk, Mette, Marleen, Rint
Programming the sensors	Daan
Creating the visualization of the data	Thiago
Research and buy the sensors	Twan, Thiago
Documentation outline	Luuk
Complete documentation & validation	Everyone

Chapter 7: Methodology

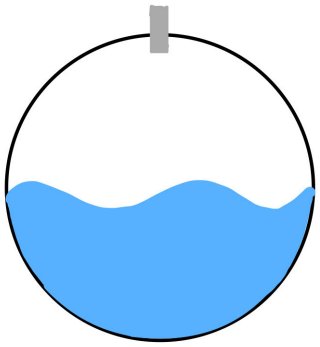
The best way to prevent big blockage in the sewer lines is detecting where there is or is a higher chance of being a blockage. The way we plan to prevent this is by measuring the water height and speed at several locations. When you are measuring this information for a longer period you get to know the normal flow rates and water height for all the locations. So, you know that when there is heavy rainfall there is an increase in all the numbers, and vice versa. And we hope that through our system it will be significantly easier to detect a blockage and then send a group of experts to remove it. The way the blockage is going to show up is by an increased water height and decreased water speed. This is caused by the blockage as there can not flow as much water through as normal, so the water piles up.

Equipment needed:

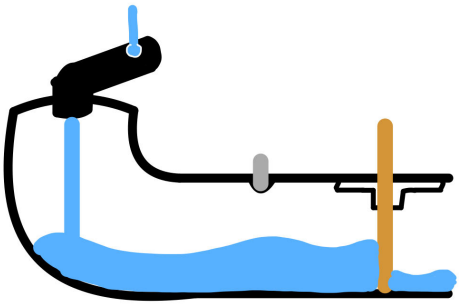
- waterproof water height sensor (ultrasound sensor) (3x) (sponsored by the lovely father of Mette, Evert Jan)
    - https://www.microsonic.de/en/distance-sensors/cylindrical/picoplus.htm
- arduino
- network cable
- power supply
- voltage converter
- program to display the network
- materials for the prototype
    - ground surface
    - pipes to represent the sewage systems
    - something to represent the blockage

Data collection:
We collect the data from different points in the sewage system and compare them to each other. We collect the water height and show the values in an online program.

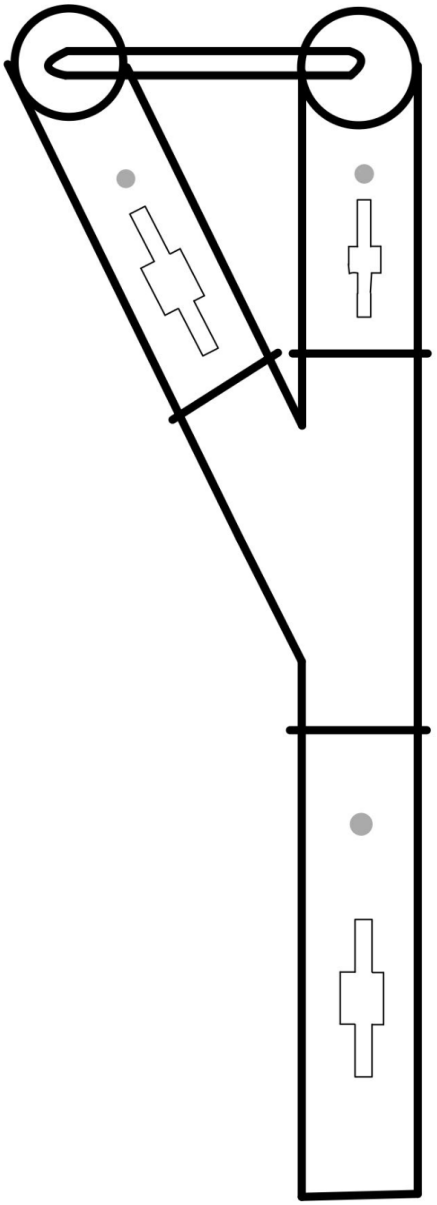
Data use/analysis:
There are three values coming into the program. These are labeled with X, Y and Z and correspond to one sensor in the prototype. We compare the water levels between those sensors and then look at the difference to predict where the blockage is most likely to be. For example if the water level at sensor X is high and the water level at sensors Y and Z are low, you can expect the blockage in the pipe with sensor X.
This data can be used by sewage companies to remove the blockage as fast as possible, since now they know where the blockage is most likely to be.



An intersection of the pipes we are going to use. On the top of the pipe the sensor is attached.



An intersection of the pipe from the side. A blockage is added to prevent the water from flowing.

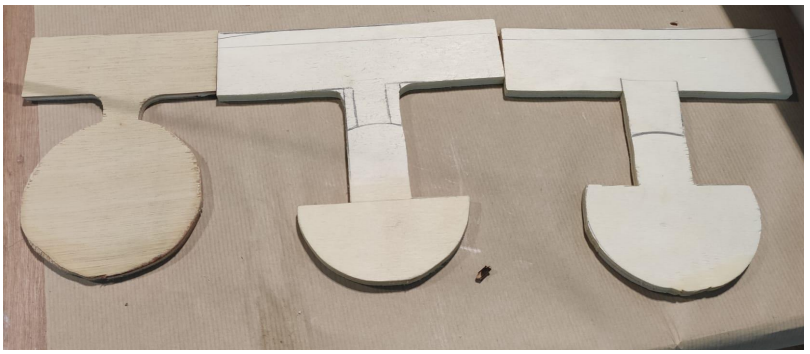


This will be the top view of the whole prototype. There is an Y-intersection to connect the three pipes. The gray dots represent the sensors and the rectangles are cuts in the top of the pipe through which we can insert a blockage.

Chapter 8: Validation

Set-up

Now that we had the methodology clear, it was time to start building. We started by cutting PVC pipes in the desired length and connecting them using specific attachments. We then drilled holes in the pipes that would serve as places where we could create a blockage. To block the pipes we cut wooden planks to the right size. We created three different sized blockages to mimic different degrees of blockage. These wooden pieces can slide into the holes created in the PVC and then twist to block the water flow.



After we completed the blockage system we cut holes in the pipes for the sensors. All sensors came with a nut that they could be screwed into. This gave us a little bit of room to change the height of the sensor, something that would come in handy later when testing. To connect the sensors to the Arduino we use a power supply, since they need more than 5V, and a voltage converter to transfer the given measurements to the analog pins of the Arduino.

With the individual pipes now done we mounted them to the attachment pieces and we had our sewage system. To provide a water flow to the system we added another PVC pipe that, using 90 degree attachment pieces, 'lays' in the main pipe. This smaller pipe also has a hole in it to allow water into the system.

We also have a lid with a small tap for the front pipe to keep water in the system when needed and monitor the water flow out of the system.

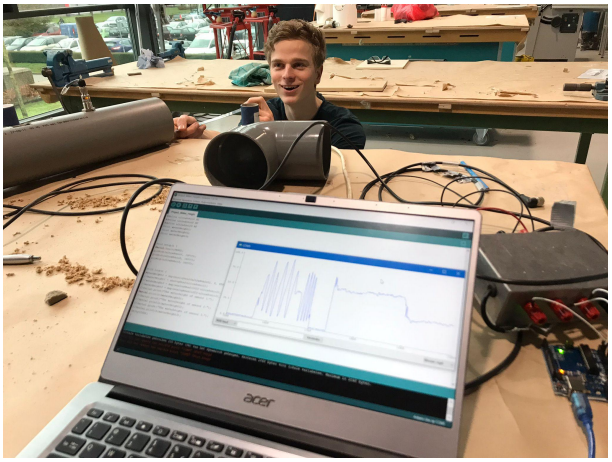
Results

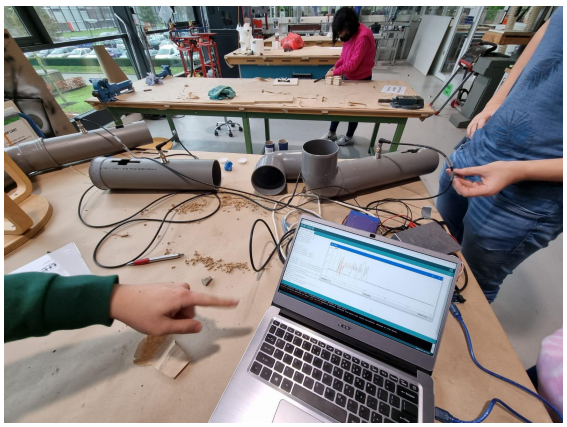
With our prototype finished, it was time to start testing the system. We started with testing our wooden blockage pieces. We did this by using two attached pipes, we then put the blockage in the pipe closest to the water and let water flow into the pipes. We then measured the difference between the water level before and after the pipe. These are the results for this test:

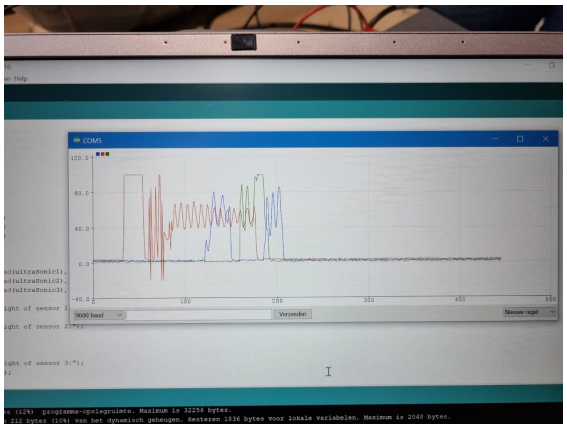
Size of blockage	Small	Medium	Large
Difference in water level (level in front of blockage - level behind blockage)	1-2cm	3-4cm	5-7cm

From the difference in water level between the two points it can be clearly seen that the difference the blockages make is large enough to be picked up by a proper ultrasound sensor.

To make sure that the difference of the water level would indeed be enough, we also had to test the sensors. We started by testing one sensor by screwing it into a loose pipe and connecting it to the power supply and the converter. We used the Arduino to draw a graph of the values measured. To mimic water changing in height we used a ruler that we would move up and down and another ruler to measure the height. We started by simply using the standard 0-1023 values of the Arduino analog pin.



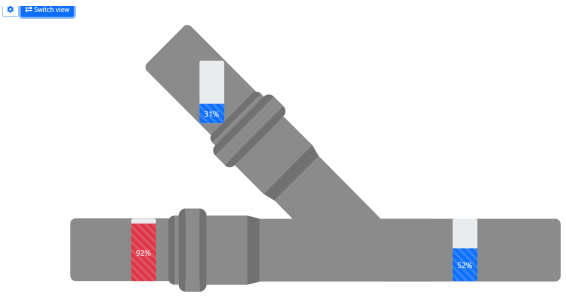




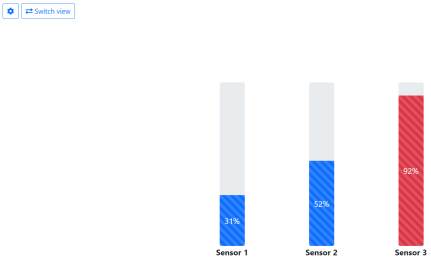
After we noticed that this worked we tried to convert these measurements into height by mapping the values from 2.5 (deadzone of the sensor, found on the box of the sensor and double checked with previously mentioned ruler system) to 11 (diameter of the pipe). This worked but we noticed that the preciseness suffered a lot from this since values would move in increments of 0.5 cm. Since we have extremely accurate sensors we decided to map the values as a percentage of the pipe's diameter where 100% means the water has reached the 2.5cm deadzone of the sensor and 0% means the pipe is empty. After we got one sensor working properly we then used all three and tested them separately. After we had already put in the work for 1 pipe, connecting three went relatively easy. We yet again tested all of them by using the two rulers and we also confirmed the dead zones on all of them which luckily were all 2.5cm.

Display

To give an overview of all the measured values of the waterheight we have a website. The sensors are connected to the arduino, which sends them to the computer connected to the arduino, which can then be seen on the website. There are two different modes to view the water levels on the website, one to display all the sensors as a network like we have made it in real life and another to see the sensor readings next to each other.



The website which shows the network



The website with the readings next to eachother

The water level is expressed as a percentage of the total height we can measure and turns red above 80% to highlight a possible blockage location. As can be seen in the example above, there must be a blockage near the sensor which is reading 92%, as the water flows to the right and the water height is much lower further down the pipe.

This is a small scale example, but could be implemented on a larger scale and should still function in a similar manner. Ideally this system would be implemented on a large sewage system to monitor blockages on a large scale. The bigger the system is, the more the advantages of our system should show since the location of the blockage remains easy to find.

Project_Water_Height §

```
#define ultraSonic1 A0
#define ultraSonic2 A1
#define ultraSonic3 A2
int waterHeight1;
int waterHeight2;
int waterHeight3;

void setup() {
  Serial.begin(9600);
  pinMode(ultraSonic1, INPUT);
  pinMode(ultraSonic2, INPUT);
  pinMode(ultraSonic3, INPUT);
}

void loop() {
  waterHeight1 = map(analogRead(ultraSonic1), 0, 850, 100, 0); //The measurement becomes a value between 0 and 100, with 0 being no water and 100 the highest water level
  waterHeight2 = map(analogRead(ultraSonic2), 0, 850, 100, 0);
  waterHeight3 = map(analogRead(ultraSonic3), 0, 850, 100, 0);

  Serial.print("X"); //The data is sent to the computer to be read with our own protocol
  Serial.print(waterHeight1);
  Serial.print("Y");
  Serial.print(waterHeight2);
  Serial.print("Z");
  Serial.print(waterHeight3);
  Serial.print(",");
  delay(100);
}
```

Chapter 9: Results and Conclusion

By creating the prototype, we tried to test and show the idea that we have. On our scale the tests worked, but will it also work on a way larger scale? We do think that it will work on a way larger scale as the prototype tried to mimic a real sized sewer system. But to create it on a larger scale you need to create a network of devices that are collecting data and sending it to a server that puts all the data together. So you have multiple computers, each with multiple sensors on them. Each computer will have their own internet and power connection. Depending on the availability of internet cables, the data could be wirelessly transmitted(i.e. 5g network or by wire). The cables that deliver power and internet can come up to the street via existing ways(i.e. side of the road where water goes into the sewer) or there needs to be a new way dug.

The advantages of this idea is that it is applicable to existing sewer lines as it runs mostly on the inside(top) of the sewer. When thinking about the solution we took in consideration that a sewer line is not a clean place and contains a lot of sand and branches that could destroy things inside the sewer line, and that a sewer line is built to last really long. The fact that it does not have any moving parts and is put on the “roof” of the sewer line does contribute to the longevity of the system.

We think that this network can be a really useful tool to use. But we do understand that this is not a small or easy solution because it does require a lot of sensors, cables and computers to make this network work in a whole city. Also the location, the inside of sewer lines, is not the easiest place to install things. Some of the sewer lines are really old and make it not easier to install all the sensors. A possible solution could be to make a hole in the roof of the pipe and place the sensors there, just as we did in our prototype. This does bring the danger of leakages and weakening the pipe but saves a lot on the installation of the sensors.

When taking the advantages and disadvantages in consideration we do think that placing and using this network is definitely worth it. The reliability and longevity make this system a good investment, especially if you develop a system that can remove a blockage by itself. It is a very potent system that can make sure that the sewage will always work in a big city or a city that has a lot of floods.

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